Calculation of Neutron Spectra in β-delayed Neutron-Emission

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Nuclear fission produces both "prompt" and "delayed" neutrons. The fraction of delayed neutrons, which are emitted after β-decay of parent precursors, is small. However, they still contribute to the neutron multiplicity of the nuclear criticality systems.

We have previously discussed β-decay half-life and β-delayed neutron-emission calculations in our microscopic QRPA-FY model [1]. This and other models of ours are able to provide not only calculated values for β-decay half-lives $T_{1/2}$ and β-delayed neutron-emission probabilities P_n for decays from the nuclear ground state but also provide these for decays from spin-isomeric states [2]. In addition they provide single-particle levels and complete β-strength functions for nuclei throughout the nuclear chart.

We have now started a program to calculate β-delayed neutron spectra. The first step is to calculate the relative β-decay intensities from a fission-fragment parent precursor ground-state to all accessible states in the daughter nucleus. As an example we show in Fig. 1 the calculated β-strength function in the decay of ^{147}Cs. The intensities of the decays are obtained by multiplying the strength functions with the phase space factor for electron and neutrino emission. The wide arrows in the figure indicate the one, two, and three-neutron separation energies S_{1n}, S_{2n}, and S_{3n}, whereas the thin arrow is the Q value for the decay: only states below this energy can be populated in the decay. The fraction of the decays that terminate in states above S_{in} (and below Q_β), that is 11.81% of the decays may emit a neutron.

For each state in the daughter nucleus (^{147}Ba, when the precursor is ^{147}Cs) above the neutron separation energy, we calculate the neutron emission probabilities to the ground and excited states of residual nucleus (^{146}Ba), using the Hauser-Feshbach statistical model. Figure 2 shows the calculated β-delayed neutron spectrum for ^{147}Cs, compared with the ENDF delayed neutron data.

We plan to extend these calculations to all fission products. Model issues that remain to be studied are how or if to account for the spins of the parent and daughter states and how or if to account for the influence of first forbidden transitions on the delayed neutron spectra.

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[1] P. Möller and J. Randrup, *Nucl. Phys. A* **514,** 1–48 (1990).
[2] Bernd Pfeiffer, et al., *Prog. Nucl. Energy* **41,** 49–69 (2002); B. Pfeiffer, et al, "Status of Delayed-Neutron Precursor Data: Half-lives and Neutron Emission Probabilities," Los Alamos National Laboratory report LA-UR-00-5897 (December 2000).

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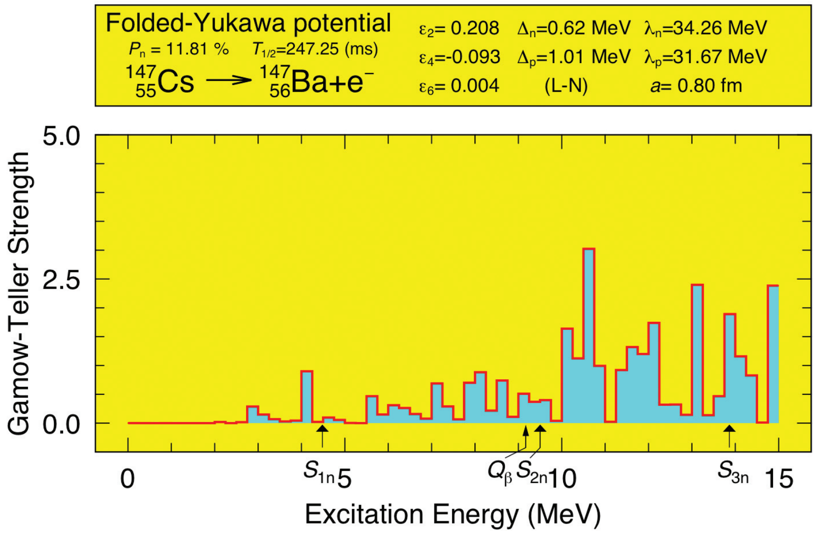

Fig. 1.
Calculated β-strength function for ^{147}Cs β-decay to ^{147}Ba.

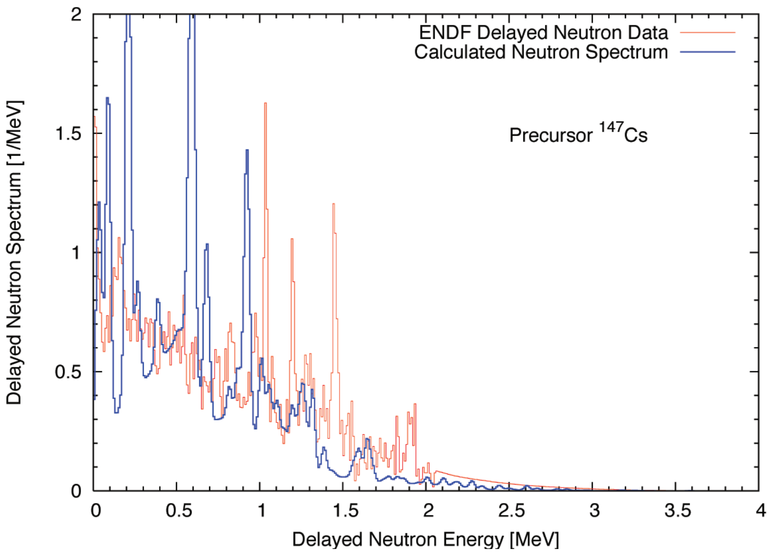

Fig. 2.
Calculated β-delayed neutron spectrum following the β-decay of ^{147}Cs, compared to ENDF data.